(12) UK Patent Application (19) GB (11) 2 184 884 (13) A

(43) Application published 1 Jul 1987

(21) Application No 8531451

(22) Date of filing 20 Dec 1985

(51) INT CL⁴
H01L 29/747

(52) Domestic classification (Edition I):
H1K 1AB1 9B1 9B1A 9R2 ABA
U1S 2213 H1K

(56) Documents cited
None

(58) Field of search
H1K
Selected US specifications from IPC sub-class H01L

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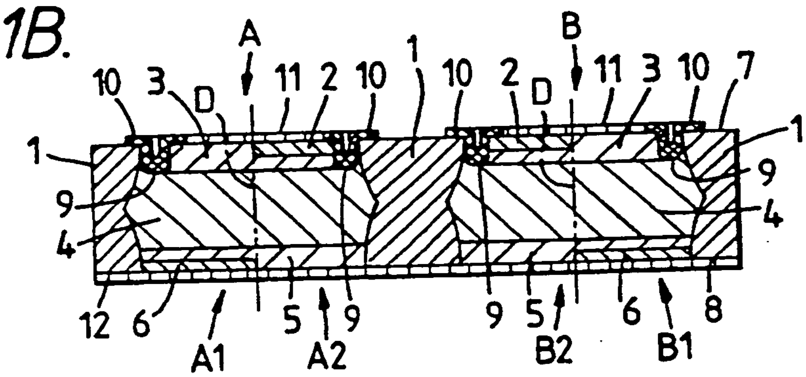
(54) Bipolar semiconductor device

(57) An overvoltage or transient suppression means is formed of a bipolar semiconductor device comprising two side by side triac structures (A,B) isolated from each other by an isolation region 1 within a single semiconductor body. The isolation region forms back to back p-n blocking junctions between the n-type bases 4 of each triac structure, the breakdown voltage of these back to back junctions being greater than the breakdown voltage of the four p-n junctions between n-type base regions 4 and p-type regions 3 and 5 in the two triac structures. The triac structures may be connected by a common metallisation 12 permitting A and B to be connected in parallel or in series via metallisation 12. Each triac structure may have symmetric or non-symmetric breakdown characteristics as required, permitting a total of up to six different breakdown voltages to be exhibited by the device. A device with symmetrical breakdown characteristics may be used in the protection of telephone equipment at the connection of a two wire circuit to a telephone exchange.

Fig.1B.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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Fig.1A.

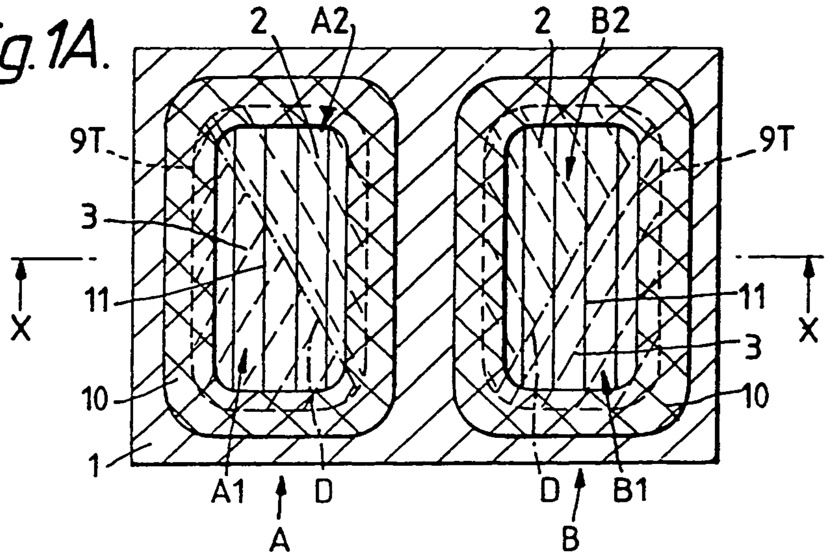


Fig.1B.

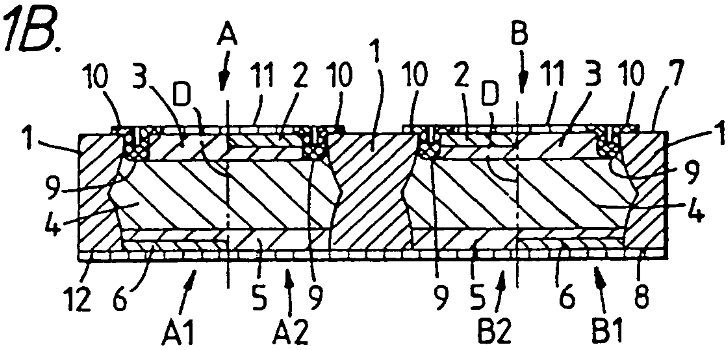
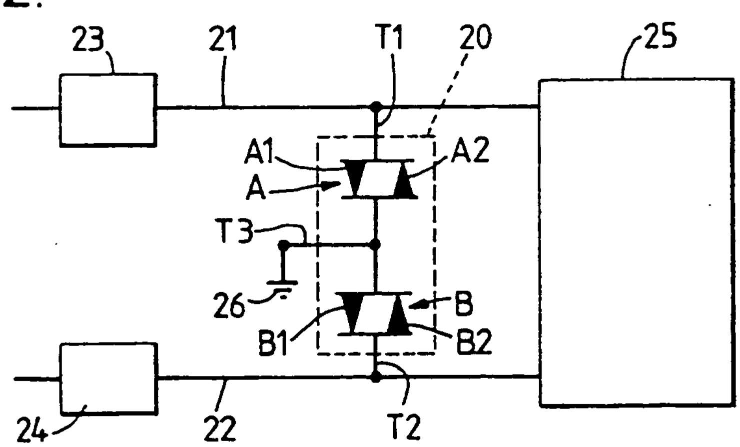


Fig.2.



SPECIFICATION

Bipolar semiconductor device

The present invention relates to bipolar semiconductor devices having a semiconductor body comprising a triac structure which includes a base region of one conductivity type located between a first and a second region of opposite conductivity type which respectively adjoin a first and a second opposite major surface of the body and which contain end regions of the said one conductivity type of said triac structure.

A bipolar semiconductor device comprising a triac structure which exhibits a resettable switching action is a two-terminal four junction double shorted—emitter negative resistance switch as described in the paper by Aldrich and Holonyak in the Journal of Applied Physics Volume 30, November 11, Published 1959, pages 1819–1824. The known device exhibits a bidirectional switching action in that it switches from a high impedance blocking state to a low impedance conducting state at a threshold voltage and that low impedance state remains while a current greater than a holding current flows through the device. When the current through the device is removed or drops below the holding current, the device reverts to the high impedance state. The threshold voltage in each direction may, within the errors in manufacture of the device, be made equal making the device a symmetrical switch. Breakover voltages in the range 24 volts to 'well over 200 volts' were reported by the authors.

According to the present invention there is provided a bipolar semiconductor device having a semiconductor body comprising a triac structure which includes a base region of one conductivity type located between a first and a second region of opposite conductivity type which respectively adjoin a first and a second opposite major surfaces of the body and which contain end regions of the said one conductivity type of said triac structure, characterised in that the body contains at least two said triac structures located side by side in the body, in that said second opposite conductivity type regions of the two triac structures are electrically connected together, and in that there is interposed between said base regions of the one conductivity type of the two triac structures an isolation region which forms with said base regions back to back p-n junctions having a higher breakdown voltage than the breakdown voltage of the p-n junctions between the base region and the first and second opposite conductivity type regions of each of the two triac structures.

In a semiconductor device formed in accordance with the invention each triac structure separately exhibits bidirectional switch characteristics at a threshold voltage dependent on the breakdown voltage of the p-n junctions between the base and the first and second opposite conductivity type regions within each triac. The connection of the second conductivity type regions of the two triac structures and the presence of the isolation region between the base region of each triac structure allows the triac structures to be placed in series within the semiconductor body.

The isolation region may also extend around each triac structure and two mesas may be present at the first major surface, each mesa being bounded by a trough which separates the mesa from the isolation region with the first opposite conductivity type region and the associated end region of each triac structure present in the mesas. The isolation region around each triac structure isolates each triac structure from the edges of the semiconductor body, and the troughs at the first major surface bound each mesa to provide an area on the top of each mesa on which electrode metallisation may be provided to connect the first opposite conductivity type region and the associated end region of each triac structure. The isolation region and troughs may conveniently be provided by known techniques including aluminium diffusion and etching respectively.

The device may further include a common metallisation on the second major surface of the body to provide the connection between the second opposite conductivity type regions and the associated end regions of the two triac structures. The electrode metallisation on top of each mesa may be connected to a first and a second terminal of a bipolar semiconductor device in accordance with the invention and the common metallisation may be connected to a third terminal of a device in accordance with the invention, such that the device exhibits a high impedance between each of the first and second terminals and the third terminal up to a threshold voltage at which switching to a low impedance state occurs and exhibiting a high impedance between the first and the second terminals up to a threshold voltage whch is the sum of the threshold voltages between the first terminal and the third terminal and the second terminal and the third terminal. Such a semiconductor device may be used in a two wire signal transmission circuit, such as a telephone circuit, as a transient and overvoltage suppression means. At the connection of the two wires to an exchange the two triac structures form two parallel bidirectional switches, between each of the two wires and earth, switch one connected via the first terminal to one of the two wires, the other connected via the second terminal to the other of the two wires, with earth connected to the third terminal, each switch exhibiting a high

impedance to earth up to a threshold voltage at which switching to a low impedance occurs, and the device exhibiting a high impedance between the two wire up to a threshold voltage which is the sum of the threshold voltage of each switch. In a two wire telephone circuit the higher threshold voltage exhibited between the lines in comparison to between each line and earth ensures that a transient on one line is dissipated to earth alone and that part of the transient is not transmitted to the second line.

In a semiconductor device in accordance with the invention, for at least one of the triac structures the breakdown voltage of the p-n junction between the base and the first opposite conductivity type region may be different from that of the p-n junction between the base region and the second opposite conductivity type region; the breakdown voltage between the base region and the first opposite conductivity type region of one triac structure may be different from that of the other triac structure; and the breakdown voltage etween the base region and the second opposite conductivity type region of one triac structure may be different from that of the other triac structure. The breakdown voltage of each p-n junction may be varied by known means, for example, the variation of the carrier concentration on either side of the junction, and a semiconductor device having such different junction breakdown voltages may be tolerated to have a different breakdown voltages between each of the three electrode metallisations of the device.

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1A shows schematically in plan a semiconductor device in accordance with the invention,

Figure 1B shows a view on X–X of Fig. 1A, and

Figure 2 shows schematically a two wire telephony circuit having transient suppression means which includes a semiconductor device in accordance with the invention.

In Figs. 1A and 1B the dimensions of the semiconductor device are shown greatly enlarged and the relative thicknesses the parts of the device as shown in Fig. 1B are exaggerated for clarity.

A semiconductor device in accordance with the invention includes two triac structures A and B formed within a semiconductor body, the triac structures being located side by side in the body and separated one from the other and bounded within the semiconductor body by an aluminium doped isolation region 1 which extends through the thickness of the semiconductor body. Suitable methods of providing the aluminium diffusion are described in British Patent 1536545 (Mullard) and British Patent 2031649 (General Electric).

The two individual triac structures A and B are of similar construction, each comprising a pair A1,A2,B1,B2 of four layer structures the division between the four layer structures being indicated by dot-dash line D. The layers are of alternating n,2,4,6 and p,3,5 type conductivity layers, the p layer 3 and the n layer 2 within it at a first major surface 7 of the semiconductor body the p layer 5 and the n layer 6 within it at a second major surface 8 of the semiconductor body and the n base, layer 4 is disposed within the semiconductor body between p layers 3 and 5. In Fig. 1A the layers 2 and 3 shown in dashed cross hatching. The p and n layers 2 and 3 are each bounded by troughs 9 partly filled by glass passivant 10 which also extends over part of the upper surface 7. The troughs are interposed between the layers 2 and 3 and the isolation region 1, the boundary between the troughs and layers 2 and 3 being shown as dashed line 9T in Fig. 1A. Electrode metallisation 11 is provided to connect the layers 2 and 3 of each triac structure A and B, this metallisation is bonded by the glass passivant 10. The common metallisation 12 extends over the whole of the lower surface 8 to provide connection between the triac structures A and B via the layers 5 and 6 of each triac structure. The parts of the troughs 10 between the devices A, B may be widened to a single wide trough to isolate the isolate region 1 between the n-bases of A and B from the first surface of the body.

The semiconductor device described above may be represented by the circuit symbol shown within the dashed line 20 in Fig. 2. In Fig. 2 a two wire 21,22 telephone circuit with line impedances 23,24 is connected to exchange equipment 25 and the device 20 has one terminal T1, T2 connected to a wire 21, 22 respectively and one terminal T3 to earth 26 to provide a self activating leakage path for overvoltage transients appearing on the wires which would otherwise damage the exchange equipment 25. Within dashed line 20 the circuit symbol is annotated to correspond with Figs. 1A and 1B with the triac structures A and B and the four layer structures within each triac A1,A2,B1,B2. The characteristics of such a device are that it remains in the high impedance state to earth at the normal 50V operating voltage of the telephone circuit and switches to a low impedance state to earth when a voltage in excess a threshold voltage of 150 volts to earth appears on the circuit, to protect the exchange equipment against UK mains voltage of 240 volts RMS and against other transients of greater voltage than the threshold voltage. When the transient or overvoltage is removed the device resets to the high impedance state as the holding current necessary to maintain the low impedance state of the device is higher than the maximum working current of the telephone circuit. The device

20 is required to be symmetrical in operation, that is it breaks down to a low impedance state in A or B when a positive or negative voltage above the threshold is applied to line 21 or 22 respectively.

In operation, for example, if the metallisation 11 of A were subject to a positive overvoltage, the n-type region 2 of A2 would be shorted by p-type region 3 common to A1 and A2 and so the junction between region 3 and n-type base region 4 of A would be in forward bias. The blocking junction would therefore be the reverse biassed junction between n-type base 4 and p-type region 5, which would undergo breakdown at a voltage dependent on the n and p-type carrier concentration in regions 4 and 5 on each side of the junction. The breakdown voltage of each of the four junctions between the n-type base and p-type regions of A and B may be the same, providing symmetrical switching as would be required in the protection of telephone equipment. When the same transient or overvoltage appears on lines 21 and 22 simultaneously, both A and B can break over independently to conduct the transient or overvoltage to earth.

The isolation of the triac structures A and B, to a voltage greater than that of the breakdown voltage to earth in the same semiconductor body, allows the triac structures to be connected in series via the metallisation 12 between the wires 21 and 22. Thus between the wires 21 and 22 the threshold voltage at which the device switches to a low impedance is the sum of the threshold voltages of each triac structure A and B. If the isolation were not present, the threshold voltage between the lines 21 and 22 would be the same as the threshold voltage between each line and earth, as without the isolation the n-base region 4 would allow an above threshold positive voltage transient appearing for example on wire 21 to cause breakdown in the device which would allow conduction of the transient to earth and to wire 22. Thus the presence of the isolation 1 ensures conduction of overvoltage transients to earth alone.

The above example of a circuit in which such a device is used requires the device to have symmetrical breakdown characteristics. Non symetrical breakdown characteristics may be obtained in a device with a different breakdown voltage at each blocking junction as required. The breakdown voltages are dependent on the carrier concentration on either side of the blocking junction. Thus a blocking junction may be given a different breakdown voltage by changing the doping concentration of one or both regions on either side of the blocking junction, or by locally enhancing or reducing these doping concentrations at a selected area of the junction. By ensuring that the breakdown voltage of the p-n junction between the n-type base regions 4 and the isolation region 1 is always greater than the largest n-type base 4-p-type region 3,5 breakdown voltage, a device may be provided which has the characteristics of two devices having, for example, different breakdown voltage at each blocking junction and where the devices are isolated within a single semiconductor body, but are interconnected by a common metallisation. In the device in accordance with the invention shown in Fig. 1B which would be packaged as a three terminal device similar to that shown in Fig. 2, reference numeral 20, the device may be used with A or B operating alone, or A and B operating in parallel or A and B operating in series, by appropriate connection to the three terminals. As the blocking junctions in the triac structures may have different breakdown voltages, appropriate interconnection of the device allows a variety of breakdown voltages to be achieved as shown in the following Table 1.

In Table 1 the first noted electrode is at a positive voltage with respect to the second, and A and B refer to the two triac structures shown in Fig. 1B. For ease of understanding the table and, for example only, the device is assumed to have blocking junction voltages of 200V (n-type base 4 to p-type region 3 in a), 100V (n-type base 4 to p-type region 5 in A), 150V (n-type base 4 to p-type region 3 in B), 60V (n-type 4 to p-type region 5 in A).

Table 1

Electrode	*Connection*	*Breakdown Voltage*
11A to 11B	Series via 12	100V+150V=250V
11B to 11A	Series via 12	60V+200V=260V
11A to 12	A only	100V
12 to 11A	A only	200V
11B to 12	B only	60 V
12 to 11B	B only	150V

A semiconductor device in accordance with the invention may therefore exhibit symmetrical or non-symmetrical breakdown characteristics dependent on the carrier concentration of the regions of the device between which regions the blocking junctions of the device are formed. The above table is to be taken as a non-limiting example, given for the purpose of illustrating that a device in accordance with the invention may, by appropriate connection, exhibit six different breakdown voltages. Other devices in accordance with the invention may exhibit breakdown voltages of which the non-symmetry lies between the fully symmetrical characteristics of the semiconductor device for transient and overvoltage suppression in a telephone circuit and the non-symmetrical

characteristics tabulated in Table 1.

CLAIMS

1. A bipolar semiconductor device having a semiconductor body comprising a triac structure which includes a base region of one conductivity type located between a first and a second region of opposite conductivity type which respectively adjoin a first and a second opposite major surfaces of the body and which contain end regions of the said one conductivity type of said triac structure, characterised in that the body contains at least two said triac structures located side by side in the body, in that said second opposite conductivity type regions of the two triac structures are electrically connected together, and in that there is interposed between said base regions of the one conductivity type of the two triac structures an isolation region which forms with said base regions back to back p-n junctions having a higher breakdown voltage than the breakdown voltage of the p-n junctions between the base region and the first and second opposite conductivity type regions of each of the two triac structures.

2. A bipolar semiconductor device as claimed in Claim 1, in which the isolation region also extends around each triac structure.

3. A bipolar semiconductor device as claimed in Claim 1 or Claims 2, in which two mesas are present at the first major surface and each mesa is bounded by a trough which separates the mesa from the isolation region, and the first opposite conductivity type region and the associated end region of each triac structure are present in the mesas.

4. A bipolar semiconductor device as claimed in Claim 3, in which electrode metallisation is present on the top of each mesa to connect the first opposite conductivity type region and the associated end region of each triac structure.

5. A bipolar semiconductor device as claimed in any preceding claim, which includes a common metallisation on the second major surface of the body to connect the second opposite conductivity type regions and the associated end regions of the two triac structures.

6. A bipolar semiconductor device as claimed in Claim 5, the device having a first, a second and a third terminal, the first and second terminals being connected to electrode metallisation on each first opposite conductivity type region and associated end region of the two triac structures, the third terminal being connected to common metallisation on the second major surface, the device exhibiting a high impedance between each of the first and the second terminals and the third terminal up to a threshold voltage at which switching to a low impedance state occurs and exhibiting a high impedance between the first and the second terminals up to a threshold voltage which is the sum of the threshold voltages between the first terminal and the third terminal and the second terminal and the third terminal.

7. A two wire signal transmission circuit having transient and overvoltage suppression means, the suppression means including a semiconductor device as claimed in Claim 6, in which the two triac structures form two bidirectional switches between each of the two wires and earth, one switch connected via the first terminal to one of the two wires, the other switch connected via the second terminal to the other of the two wires, and earth connected to the third terminal, each switch exhibiting a high impedance to earth up to a threshold voltage at which switching to a low impedance occurs, and the device exhibiting a high impedance between the two wires up to a threshold voltage which is the sum of the threshold voltage of each switch.

8. A semiconductor device as claimed in any one of the preceding claims, in which, for at least one of the two triac structures, the breakdown voltage of the p-n junction between the base and the first opposite conductivity type region is different from that of the p-n junction between the base region and the second opposite conductivity type region.

9. A semiconductor device as claimed in any one of the preceding claims, in which the breakdown voltage between the base region and the first opposite conductivity type region of one triac structure is different from that of the other triac structure.

10. A semiconductor device as claimed in any one of the preceding claims, in which the breakdown voltage between the base region and the second opposite conductivity type region of one triac structure is different from that of the other triac structure.

11. A two wire signal transmission circuit as claimed in Claim 7, in which the circuit is a telephone circuit and the suppression means is provided at the connection of the circuit to an exchange.

12. A semiconductor device substantially as hereinbefore described with reference to Figs. 1A and 1B.

13. A telephone circuit having transient and overvoltage suppression means substantially as herein described with reference to Fig. 2.

Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon) Ltd. Dd 8991685, 1987.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.